

PATH TRACKING ANALYSIS

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2012

“I declare that this report entitle “*Path tracking analysis*” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

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Date : 2 July 2012

To my beloved mother and father

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Bismillahirrahmanirrahim,

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ABSTRACT

This project is about the development of path tracking mechanism and how to evaluate its performance. There are a lot of path tracking robot that have been used in various environment and this type of robot also has been used for different purpose such as military , emergency and domestic purpose. Therefore in this project also present appropriate method to evaluate path tracking mechanism performance that has been developed. Mobile robot is used to integrate with path tracking mechanism that has been developed in order to evaluate its performances. In order to evaluate path tracking robot two characteristics must be concerned which is path tracking robot and settling time. These characteristics will determine the performance level for path tracking mechanism. Mobile robot is used in this project because this type of robot is common robot that always used to integrate with path tracking concept. In this project also present the study effect of sensor configuration to the path tracking performances. There are two set of sensor that used in this study where sensor A have smaller gap between array of sensor and sensor B have bigger gap between array of sensor. The result will justify the effect of gap between sensors to the performance of path tracking mechanism. From the analysis show that by decrease the gap between sensor will increase the performance of path tracking mechanism and vice versa. By completing this project hopefully can developed the best performance of path tracking mechanism at low cost.

ABSTRAK

Projek ini adalah mengenai pembangunan mekanisme pengesan laluan dan cara untuk menilai prestasinya. Terdapat banyak robot pengesan laluan yang telah digunakan dalam persekitaran yang pelbagai dan robot seperti ini juga telah banyak digunakan untuk tujuan yang berbeza contohnya seperti untuk ketenteraan, kecemasan dan juga untuk tujuan domestik. Oleh itu, dalam projek ini akan dibentangkan kaedah yang sesuai untuk menilai prestasi mekanisme pengesan laluan yang telah dibangunkan dalam projek ini. Tiga ciri yang perlu diberi perhatian ialah kesilapan pengesan laluan dan penepatan masa. Kedua-dua ciri ini akan menentukan tahap prestasi mekanisme pengesan laluan. Mobil robot digunakan untuk disepadukan dengan mekanisme pengesan laluan yang telah dibangunkan untuk dinilai prestasinya. Ini disebabkan mobil robot selalu digunakan untuk disepadukan dengan konsep pengesan laluan. Di dalam projek ini juga membentangkan kajian kesan konfigurasi sensor terhadap prestasi pengesanan laluan. Terdapat dua jenis konfigurasi dimana sensor A mempunyai ruang antara sensor yang lebih dekat manakala sensor B mempunyai ruang antara sensor yang lebih jauh. Hasil dari kajian ini akan membuktikan ruang antara sensor memberi kesan kepada prestasi mekanisme pengesan laluan. Daripada analisis dapat dilihat bahawa ruang antara sensor jika dikurangkan membuatkan prestasi mekanisma pengesan laluan meningkat. Di akhir projek ini diharap mekanisma pengesan laluan dapat dibangunkan dengan kos yang rendah tetapi memberi prestasi yang terbaik.

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LIST OF ABBREVIATIONS

| | |
|------|---------------------------------|
| IR- | Infrared |
| PIC- | Peripheral Interface Controller |
| VS- | Versus |
| KPI | Key Performance Indicator |
| ADC | Analog-Digital Converter |

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Path tracking robot is a autonomous machine that have ability to follow the path or line given. It can move to a certain point depends on its sensor and algorithm that put on the robot. This type of robot always used in various environment and for different purposes such as for emergency , military and also for domestic purposes.

In this project, the development of path tracking mechanism on mobile robot is present in order to study the robot performance and gain data from the path tracking mobile robot. Data collected from the analysis on the path tracking mobile robot will be used to develop a path tracking mechanism for arm robot where have accurate and precise path tracking sensor.

Therefore the complection of this project hopefully will bring a lot of improvement to the path tracking mechanism especially for an arm robot and for future research. This path tracking mechanism can be applied to the arm robot so that it can perform the task given by applying path tracking concept.

1.2 Problem Statement

Nowadays there are a lot of path tracking robot and have been used in various environment and for different purposes such as for emergency , military and also for domestic purposes. However this path tracking concept not yet integrated to the arm robot.

Therefore the problem is how to build best path tracking mechanism at low cost and how we determined best and suitable sensor for this mechanism. In order to solve this problem

the development of path tracking mechanism is present in this project. This mechanism are integrated to mobile robot in order to perform several tests on this robot. These tests are mean to evaluate the robot performance and to determine best sensor for this mechanism. Mobile robot is choosen in this project because it is a common robot that always use to integrate with path tracking concept

In order to evaluate path tracking robot performance there are two important characteristics we need to know. There are settling time and path tracking error. All data that obtain from the evaluation of path tracking robot will be used to determined best sensor and help for development of path tracking mechanism for an arm robot and at the same time solved the problem.

1.3 Project Objective

- To develop a path tracking mechanism on a mobile robot.
- To evaluate the performance of path tracking robot using appropriate sensor and methodology .
- To integrate path tracking concept into the arm robot .

1.4 Project scope

In this project, development of mechanism for mobile robot that using path tracking concept is performed. Data that gain from analysis perform on path tracking mechanism of mobile robot will be used to integrate path tracking concept into arm robot. Therefore design and development of arm robot will not be perform in this project since arm robot is just a tool to integrate with path tracking mechanism. Moreover the development of spraying or welding mechanism also will not be perform in this project. This is because this mechanism are not include in the objective of this project.

1.5 Chapter Overview

This thesis will include report analysis of the project which comprised the evaluation of the path tracking mechanism on mobile robot. This will lead to the finding of two important characteristics such as path tracking error and settling time. In order to achieve the objective of the experiment, the second chapter, literature review is done so that given better understanding about the theory behind this project. Next chapter will present methodology that applied in this project. All software and hardware that used to complete this project will be explain in detail in this chapter too. After result derived ,that result that obtain from analysis that done by performed several test will be present in next chapter. Several discussions about result and problem that may occur during completing this project also will be presented in this chapter. Last but not least in the end of this thesis the conclusions and some recommendations for the future research of this project will be explain in the last chapter of this thesis.

1.6 Summary

In conclusion by presenting this chapter it gives better understanding about this project so that can produced the outcome at once overcome the problem that state in this chapter. More over by clearly state the objectives and scope in this chapter, it make this project easier to be accomplished. It is also help to reduce parameter of this project so that case study on literature review will be more realistic and achievable.

CHAPTER 2

LITERATURE REVIEW

2.1 Chapter Overview

A lot of literature reviews have been done to complete this project. Sources of literature review are from the articles, journals, books, thesis and some from internet. This chapter explain the understanding towards the theory behind each technology that propose by the researcher or writer in their paper.

2.2 Evaluate path tracking robot performance.

Several test must be perform in order to evaluate path tracking robot perfomance. In research article by Roth S.A. and Batavia P.H. (2002) [1], both of them agreed that high accuracy path tracking robot is very important in order to avoid collision with obstacle. For an example precision turf management[1] really need accurate path tracking in order to increase its process analysis.

When conducting test for path tracking performance there are three characteristic that must be concern about. The first one is stability. In a different speed , the path tracking robot must be stable when following the different paths given. It is important to check the stability of path tracking robot during high speed. This is because at this speed the path tracking robot and control dynamic system give a great impact rather than at lower speed.

Second characteristic is time settling which is the time required for the path tracking robot to settle onto desire path. In other mean is how much time required for path tracking robot to finish the desire path. By examining settling time, it is need for tester to know whether the system is over damped, under damped or closed to critically damp.

The third characteristic is overall tracking error. It is define as shortest distance between the path tracking robot's control point and the path given .In order to show the position of the robot's control point from path given, the tracking error is positive if the robot to the right of the path and vice versa. What need to know or result required from this test is how close the path tracking robot stays on the path given.

In order to measure the three characteristic mention above, Roth S.A. et al(2002) [1], performed a test with three different paths which path that with a step discontinuity, circular path with different radius and path with combination of straight and curve section. This is also known as "real world" path.

Step Discontinuous test was performed to measure the stability of path tracking robot, settling time and oscillation frequency. From picture, the initial straight line is used to get robot up to speed. Besides that it work as base lined to measure the third characteristic which is straight line tracking error. Which mean to calculate tracking error that occur when the robot follow the straight path type. From the picture below, obviously the system is as damped oscillator. Therefore from the settling time and oscillation frequency can be measure. In this test they using the different speed to ensure the robot stability.

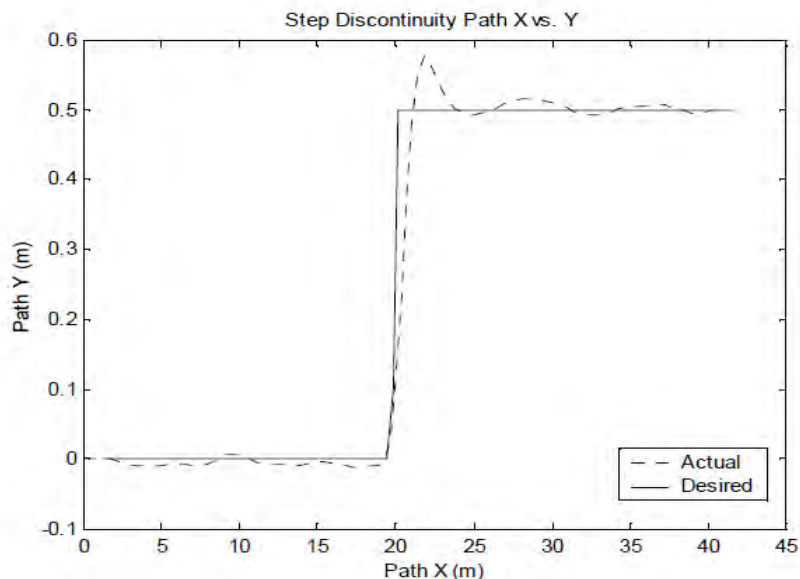


Figure 2.1: Step Discontinuous[1]

The second test is perform in circular path with different radius. They perform this test in order to measure the tracking error on the curvature (path tracking error vs. curvature).The range

of curvature that used by Roth S.A. et al (2002) [1], was from a straight line to the minimum turning radius that robot is expected to follow. Since the radius of the circular path is different, they using a constant speed on the robot so that they can see how well the robot will follow the path of different curvatures. They also state that the robot is necessary to be test several time on the smallest radius path in order to reach steady state.

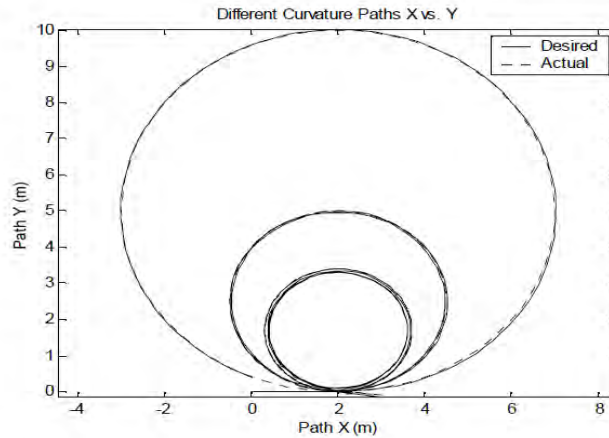


Figure 2.2: Circular Path[1]

The last test is perform on the "real world" path. This path is called as "real world" since it is combination of straight line and curved section. The purpose of this test perform by both of them is to measure the distribution of tracking error over the combination of straight and curvature path. By perform this test they know the behavior of the path tracking robot itself. For an example, if there is bias in the tracking error distribution therefore there also have bias in the control system of the robot for which the tracker must compensate.

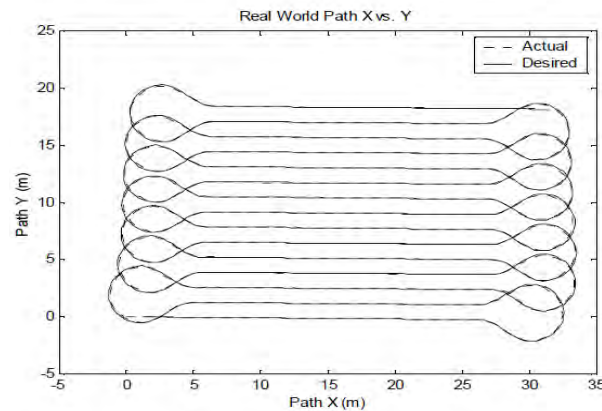


Figure 2.3:Real-time path[1]

By completing all the test they know the performance of their path tracking robot. They know the stability, settling time and how much error occur in tracking process. Besides that from the result they state that oscillations in the path must be kept at least below 5 cm so that visually obvious error can be avoided. Besides that, the robot have high accuracy, if it closely follow the path given and have fast settling time. This is because by having the fast settling time it reduce the time between leaving a turn and settling onto straight line at the same time increase the tracking process efficiency

2.3 Algorithm of path tracking robot

Every path tracking robot must have their unique algorithm so that they can able to perform their purpose which is follow the path given. In a Master Thesis by Martin Lundgren (2003) [2], there three type of path tracking algorithm available in the world which is Follow-the-carrot, Pure Pursuit and Vector pursuit. This three type of algorithm is widely used on path tracking robot today. Every type of algorithm was explained by Martin Lundgren(2003) [2]. Follow -The -carrot is all about obtain a goal point and then the robot will try to reach that point. This is the simple method that can be implement into robot. First step is to draw a line from the centre of the robot coordinate system perpendicular to the path given. then the carrot point as known as goal point is defined. This points is located on the path a look ahead distance away from the intersection points of this line. As Martin Lundgren(2003)[2] pointed out, the most

important parameter in this algorithm is orientation error (angle between current robot heading to the line drawn from the center of robot system to the goal point). If orientation error is equal to zero it means that the robot accurately heading toward the goal point. There are several disadvantage if using this algorithm. Firstly, the robot always oscillate from the path given and increase the path tracking error.

Secondly robot seem inclined to naturally cut corners. Lastly this method is not suitable for project that need good tracking ability as its outcome since this method let the robot reach the goal point without properly follow the pat given. However according to Martin Lundgren(2003) [2], this method still suitable for educational purpose especially for school project. Pure pursuit algorithm is more frequently used compare to the Follow -the -carrot since it reduce the oscillation in case of large-scale positional and heading error. Beside that this method also improve path tracking accuracy at curves. The second method is Pure Pursuit algorithm which measure the distance from robot current position to the goal point. The goal point is define as same as in Follow-the-carrot algorithm. Pure pursuit is originally come from a way people describing this method where the robot always in pursue toward the goal point. Pure pursuit algorithm is more frequently used compare to the Follow -the -carrot since it reduce the oscillation in case of large-scale positional and heading error. Beside that this method also improve path tracking accuracy at curves.

The last algorithm that proposed by Martin Lundgren(2003) [2] was Vector pursuit. This is new path tracking method and the inventor of this algorithm is Sir Robert S. Ball. The method that introduce at early 1900 is base on screw theory since it can be used to represent the motion of any rigid body in relation to a given coordinate system and only use several years ago as algorithm in path tracking robot. Martin Lundgren(2003) [2] mentioned that which is any instantaneous motion can be described as a rotation about a line in space with an associated pitch. The function of Screw control not only have the robot reach the goal point but also arrive with correct orientation and curvature. In other mean the screw control allow the robot reach the goal point with high accuracy and less error.

2.4 Sensor for Path Tracking robot.

Line follower robot is a machine that able to follow the path given autonomously. The path can be visible like white line in black surface or vice-versa. It also can be a magnetic field that invisible to human eyes. This robot have ability to sensing the line through sensor and maintaining the course by constantly correcting wrong moves based on its algorithm. Sensor is the most important component in path tracking robot. Work as detector component, it detect the line on the path so that path tracking robot able to follow the path given. In research article by Robert W. Hogg, Arturo L. Rankin, Stergios I. Roumeliotis, Michael C. McHenry, Daniel M. Hemlock, Charles F. Bergh, and Larry Matthies (2002) [3], it is known that the most crucial thing or part for the navigation system are accuracy, size and power. The sensor that integrated with the circuit must be fit within the space in the robot and the power can be afforded by chassis while delivering the resolution in order to determined robot current position. The accuracy of the navigation sensors of a robot always affect the ability of robot to follow the path given precisely. This is because, accuracy limit and resolution of the sensor used always influence by environmental and requirement of the varied operation itself. It is consistent to information by Edward Cheung and Vladimir Lumelsky (2002)[4]. In the research paper by Edward Cheung and Vladimir Lumelsky(2002) [4] it can be conclude that sensor must be accurate to detect the obstacle so that the collision between arm robot and obstacle can avoided. This research was performed by using proximity IR sensor. IR is one of active sensor that emitted and detected the beam of light. A good IR sensor can detect maximum range at least 5 inch.

In research paper by Priyank Patil(2006) [5] also explain how to determined a good sensor. According to Priyank Patil(2006) [5] the good sensor should have near zero resistance in presence of light and have very large resistance if there are no light. A good sensor also give maximum change in potentiometer if light is whether too dim or too bright. The voltage at potential meter can be calculate by using following equation: $R_{\text{sensor}}/(R_{\text{sensor}}+R_1)$. In the research performed by Priyank Patil(2006) [5] a array of IR sensor was used in the path tracking robot. An array of 8 LEDs and sensors is arrange below the robot body and facing the ground where all sensors are divide into two group which is four sensors for the left and the other four for the right..

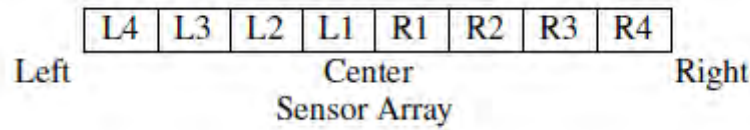


Figure 2.4:Sensor array[5]

IR is sensor that depend on amount of light reflected back and give an output as analog signal. Output signal is send to comparator so that it can provide two type of output signal which is 0s for robot on the line while 1s for robot off the line in order to fed to the microcontroller. The algorithm that used by Priyank Patil(2006) [5] is easy to understand. The robot is move by comparing between rightmost sensors and leftmost sensors. The robot will move to the direction depend on which group of sensors that read 0s more. For an example if rightmost sensors give an output as 0s more than leftmost, the robot will turn right and vice versa. If all eight sensors give an output as 1s, the robot will turn clockwise if line was last seen on right and counter clockwise if line was last seen on left.

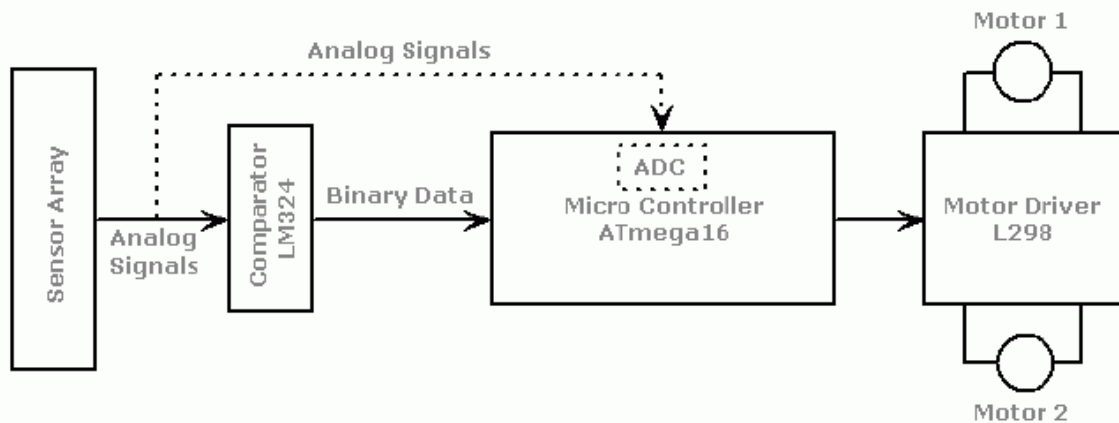


Figure 2.5:Block Diagram[5]

2.5 Mechanical structure of arm robot.

Arm robot is widely used to replace human since it can be much stronger and can do many thing that people can't do. Besides that robot is very precise and accurate in their movement so that give almost none error when do work. Besides that by using robots industrial